National Aeronautics and Space Administration

Orbital Debris Quarterly News

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Inside...

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Congressional Hearing Held on Orbital Debris and Space Traffic

In response to the accidental collision of the Iridium 33 and Cosmos 2251 satellites in February, a Congressional hearing was held on 28 April on the subject of "Keeping the Space Environment Safe for Civil and Commercial Users." Appearing before the House Committee on Science and Technology's Subcommittee on Space and Aeronautics were Lt Gen Larry James of US Strategic Command, Nicholas Johnson of NASA's Orbital Debris Program Office, Richard Dalbello of Intelsat General Corporation, and Scott Pace of George Washington University's Space Policy Institute. Subcommittee members questioned the witnesses about potential measures to improve the information available to civil and commercial users to avoid in-space collisions and discussed ways to minimize the growth of future space debris.

Figure 1. Witnesses appearing before Congressional hearing on orbital debris. From left to right, Lt Gen Larry James of US Strategic Command, Nicholas Johnson of NASA's Orbital Debris Program Office, Richard Dalbello of Intelsat General Corporation, and Scott Pace of George Washington University's Space Policy Institute.

In his statement before the Subcommittee, Johnson noted that "The recent collision of two intact satellites underscores a NASA 1970s-era finding, reiterated more recently in a NASA study published in Science in 2006, that the amount of debris already in Earth orbit is sufficient to lead to more accidental collisions, which in turn will lead to an unintended increase in space debris and increased risk to operational space systems. In the future, such collisions are likely to be the principal source of new space debris. The most effective means of limiting satellite collisions is to remove non-functional spacecraft and launch vehicle orbital stages from orbit."

Just five days before the Congressional hearing, NASA's Cloudsat spacecraft executed a collision avoidance maneuver to evade a potential collision with a fragment of Cosmos 2251.

Subcommittee Chairwoman Gabrielle Giffords (D-AZ) summarized the hearing, saying, "One thing is already clear – the space environment is getting increasingly crowded due to the relentless growth of space debris. If the spacefaring nations of the world don't take steps to minimize the growth of space junk, we may eventually face a situation where low Earth orbit becomes a risky place to carry out civil and commercial space activities." ♦

United Nations' COPUOS Receives Update on Iridium-Cosmos Collision

At its annual meeting in June, in Vienna, Austria, the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) received two updates from the United States on the February collision of the Iridium 33 and Cosmos 2251 satellites. Former astronaut and current Air Force Brigadier General Susan Helms noted that US Strategic Command is developing a capability to conduct conjunction assessments for a larger number of operational spacecraft and is looking forward to expanding its spaceflight safety products to the international aerospace community. Nicholas Johnson, of the NASA Orbital Debris Program Office, provided a technical update on the nature of the collision debris clouds and their likely evolution.

More than 1500 large (>10 cm) debris from the collision had been identified by the US Space Surveillance Network. These debris are concentrated near 800 km altitude where a large number of spacecraft perform communications and Earth observation missions.

The Cosmos 2251 debris outnumbered the Iridium 33 debris by about two-to-one, close to the ratio of their respective masses. Assuming a rapid return to normal levels of solar activity, half of the debris (principally those debris ejected in retrograde directions) might fall back to Earth within 5 years, although some will remain in orbit through the end of the century. However, if solar activity remains at low levels, as now predicted by many solar scientists, the debris could remain in orbit for significantly longer periods. ♦

MMOD Inspection of the HST Wide Field Planetary Camera 2 Radiator

The STS-125 Atlantis astronauts retrieved the Hubble Space Telescope (HST) Wide Field Planetary Camera 2 (WFPC2) during a very successful and final servicing mission to the HST in May. The radiator attached to WFPC2 (Figure 1) has a dimension of 2.2 m by 0.8 m. Its outermost layer is a 4-mm thick aluminum coated with white thermal paint. This radiator has been exposed to space since the deployment of WFPC2 in 1993. Due to its large surface area and long exposure time, the radiator serves as a unique witness plate for the micrometeoroid and orbital debris (MMOD) environment between 560 and 620 km altitude.

The NASA Orbital Debris Program Office is leading an effort, with full support from the NASA Hypervelocity Impact Technology Facility, NASA Meteoroid Environment Office, and NASA Curation Office, to conduct an MMOD impact survey of the WFPC2 radiator during the summer. The goal is to use the data to validate or improve the near-Earth MMOD environment definition. This effort is also very well supported by the HST Program located at the NASA Goddard Space Flight Center. From the on-orbit images taken during the last two servicing missions, 20 large MMOD impacts are clearly visible (Figure 2). The survey team expects to find an additional 600 to 1000 impact craters caused by MMOD particles in the size regime that are important to satellite impact risk assessments. As the project moves forward, more information will be reported in the Orbital Debris Quarterly News. ♦

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Figure 1. A view of the HST after it was captured and locked to the Atlantis cargo bay. (NASA Photo/s125e007066)

MMOD Inspection

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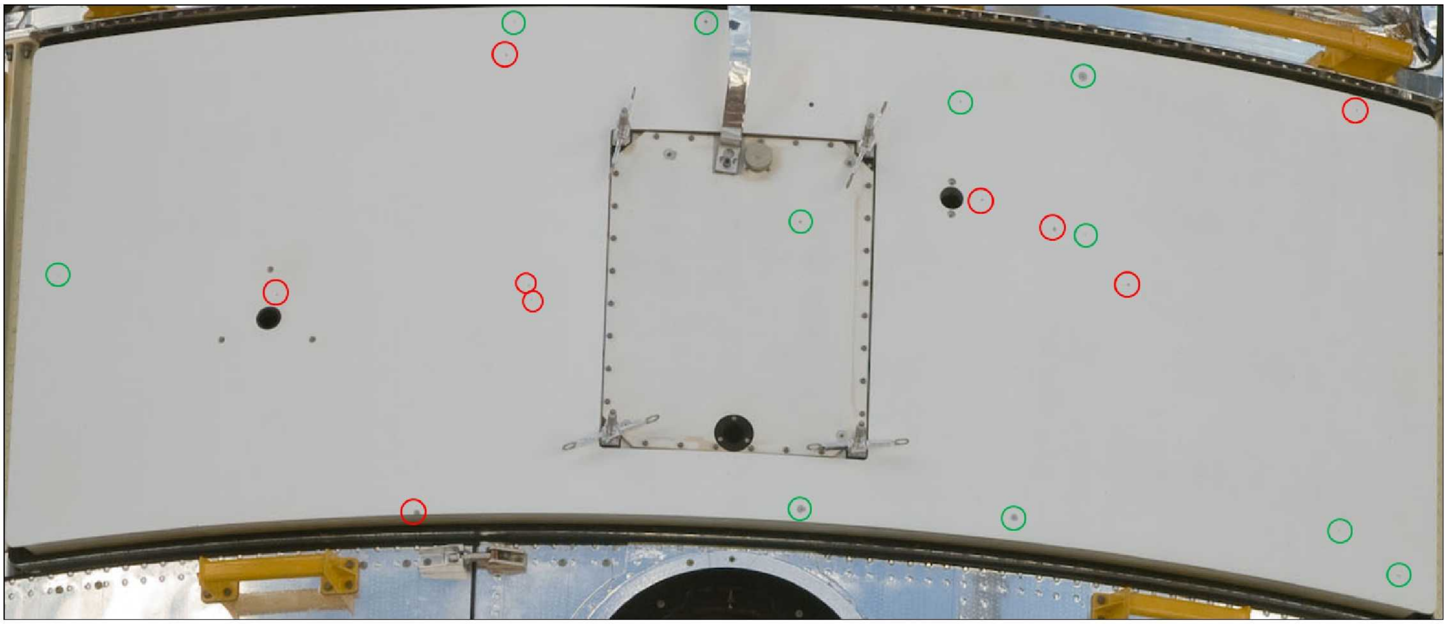

Figure 2. Large, visible MMOD impacts on the WFPC2 radiator. The largest damage area is about 1 cm across. Red circles: features identified from the 2002 HST Servicing Mission 3B image survey. Green circles: new features identified from the 2009 HST Servicing Mission 4 image survey. (NASA Photo/s125e006995)

PROJECT REVIEWS

Reentry Survivability Analysis of the Global Precipitation Measurement Spacecraft

R. L. KELLEY

The Global Precipitation Measurement (GPM) spacecraft is part of a joint NASA/Japanese Aerospace Exploration Agency (JAXA) project, planned to be launched in 2013. From the beginning, the project team's goal was to design the vehicle to reduce the risk of human casualty following reentry by reducing spacecraft component survivability and/or by executing a controlled reentry.

The NASA Orbital Debris Program Office recently performed a reentry survivability analysis for the entire GPM spacecraft. Because of several large components within the spacecraft, a detailed analysis was needed to assess compliance with NASA Standard 8719.14. GPM is being launched as a follow-on to the Tropical Rainfall Measuring Mission (TRMM) spacecraft, orbited in 1997. NASA's contribution includes the spacecraft bus and GPM Microwave Imager (GMI), as well as satellite operation through NASA's Goddard Space Flight Center (GSFC). JAXA is providing the Dual-frequency Precipitation Radar (DPR) with Ku/Ka-bands (13.6 and 35.5 GHz), the H-IIA launch vehicle, and launch operation services.

A sketch of the GPM spacecraft in Figure 1 shows the locations of the DPR (labeled separately as KuPR

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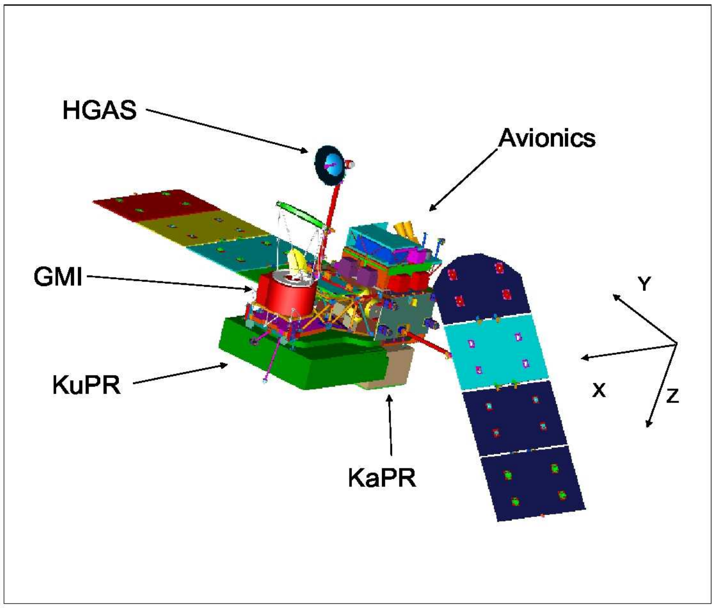

Figure 1. GPM Spacecraft with deployed solar arrays.

Reentry Survivability

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and KaPR), the high gain antenna (HGAS), the GMI, and the avionics. The GPM spacecraft will be launched into a 400 km, 65° circular orbit to meet the objective of measuring the amount and distribution of rainfall for over 80% of the globe. The data acquired by the satellite will be used to predict global climatic changes.

In order to ensure vehicle compliance with NS 8719.14, specifically Requirement 4.7-1 regarding reentry survivability, the GPM team from the beginning adopted a "Design for Demise" mind-set. To this end, debris casualty area (DCA) goals were allotted for each subsystem in much the same way that typical satellite design teams assign mass and power allotments. This added constraint on the design of the vehicle has resulted in numerous studies to help assess the survivability for various individual components. The design team used these assessments for items such as fuel tanks and reaction wheel assemblies, both of which typically survive, to identify alternate component designs which would be more likely to demise. In addition to the analysis performed on individual components, multiple iterations of the entire spacecraft analysis were performed as details of the design were refined. The ultimate goal of the project is to satisfy the requirement of NS 8719.14, which states that the risk to human casualty will not exceed 1:10 000.

All analyses for GPM were performed using NASA's Object Reentry Survivability Analysis Tool (ORSAT), with the most recent and most complete analysis containing 255 objects, representing over 85% of the total mass of the spacecraft. At the time of this latest analysis, a design decision concerning whether the propellant management device (PMD) should be made of aluminum or titanium was pending; therefore, the results of both scenarios were modeled.

The assumptions in the analysis of GPM included an uncontrolled reentry starting at 122 km, the accepted altitude for entry interface. At 78 km the main spacecraft body was assumed to break up and the primary components were assumed to split from the parent body and enter separately. Further fragmentation of these components occurred in a number of cases.

In its entirety, GPM was assumed to have a mass of 2676 kg with box-like dimensions of length = 4.28 m, width = 2.54 m and height = 2.39 m. Other assumptions included an initial temperature of 300 K for all components and an average oxidation efficiency factor of 0.5. In cases where the object survived with a high demise factor (absorbed heat divided by heat of ablation) of over 90%, a parametric analysis was considered in which the initial temperature and oxidation efficiency were varied from the nominal values.

Fourteen different materials were used in the analysis for the 255 unique components. In ORSAT, the point of object demise is assessed to occur once the total heat absorbed (net heating rate integrated over time, multiplied by the surface area) becomes greater then the heat of ablation of the object.

The final results showed 26 and 32 unique objects (93 and 99 including duplicate objects) surviving for the cases of the aluminum PMD and the titanium PMD, respectively, the difference being the six components which make up the PMD. When only the items with an impact energy greater than 15 J, the accepted hazard limit for impacting debris, are considered, only 15 of the unique components (30 including duplicate objects) for the aluminum PMD case contribute to the DCA of the GPM spacecraft. For the titanium PMD case, 21 of the unique components (36 including duplicate objects) survived with an impact energy of greater than 15 J.

Figure 2 shows the demise altitude vs. downrange for all of the GPM components modeled for the titanium PMD scenario. With the exception of a few components that have extreme ballistic coefficients, there is a near linear variation of demise altitude vs. downrange. All surviving components, regardless of impact energy, are shown in this figure with those items with a DCA greater than 15 J highlighted in yellow and PMD components highlighted in red. If the items with impact energies less than 15 J are ignored, the first object contributing to the DCA is located at a downrange distance of 18 473 km and the last is located at 19 740 km, resulting in a footprint length of 1267 km. Since all of the surviving titanium PMD components fall within these bounds, the footprint of the aluminum PMD case is identical. The total surviving mass is 75.9 kg or 2.8% of the total for the aluminum PMD scenario and 82.6 kg or 3.1% for the titanium PMD. The result is a DCA of 23.38 m^2 for the aluminum and 26.71 m^2 for the titanium PMD case. Depending on the year of reentry, this risk is approximately 1:3500 – 1:2800 depending on the case. As a result of these findings, the GPM project has selected a controlled reentry as the primary means of disposal. ♦

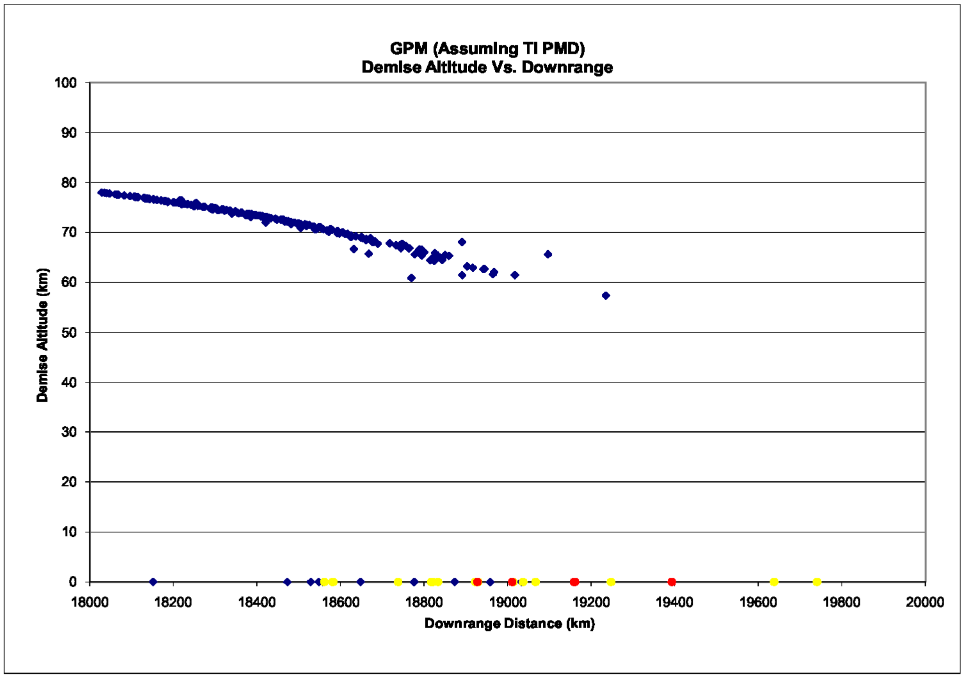

Figure 2. Demise altitude versus downrange for all GPM components.

An Update on Recent Major Breakup Fragments

J.-C. LIOU

Of the 190 known satellite breakups between 1961 and 2006, only one generated more than 500 cataloged fragments. The event was the explosion of the Pegasus Hydrazine Auxiliary Propulsion System (HAPS, International Designator 1994-029B, US Satellite Number 23106) in 1996. A total of 713 Pegasus HAPS fragments were included in the catalog.[1] Since the beginning of 2007, however, the near-Earth environment has been subjected to several major breakups. Table 1 lists the basic information of the breakups, including the cataloged fragments, fragments with Radar Cross Section (RCS) measurements, and the number of cataloged fragments remaining in orbit (as of 25 June 2009). The long-term impact of these events to the environment depends on several factors – number of fragments generated, orbital lifetimes of the fragments, and collision probabilities with respect to other objects in the environment. This article provides an update summary of the first two factors, based on the 25 June 2008 catalog data.

Leading the list of Table 1 is the Fengyun-1C (FY-1C) anti-satellite test conducted by China on 11 January 2007. It was the worst on-orbit breakup in history and the damage to the environment is severe.[2,3] The explosion of Briz-M generated perhaps more than 1000 detectable fragments (ODQN, April 2007, p 3). However, due to the availability and sensor location limitation of the US Space Surveillance Network (SSN), only 76 fragments are included in the catalog. The cause of the multiple fragmentation events of Cosmos 2421 remains unknown (ODQN, July 2008, pp 1-2). Fortunately, it is the only member of its class still in orbit and the majority of the fragments, as of June 2009, have decayed. The first ever accidental collision between two intact satellites, Iridium 33 and Cosmos 2251 (560 kg and 900 kg, respectively), highlighted the orbital debris problem in the low Earth orbit (LEO) region. Its long-term impact to the environment will need to be assessed once the data collection is complete.

Figure 1 shows the cumulative size distributions of the four major fragment clouds. The NASA Size Estimation Model was used to convert the observed RCS to the average size of each object.[4] The curves exhibit a similar pattern – a power law distribution consistent with the common understanding of the size distribution of explosion or collision fragments. However, the slopes are somewhat different. The level-off of the curves near 10 cm is similar to those of other fragment populations in the environment.[3] It is caused by the sensitivity limit of the SSN sensors.

The orbital lifetime of an object is related to its area-to-mass ratio (A/m) and the perigee and apogee altitudes of its orbit. The A/m of each fragment was empirically determined from its TLE history. An iterative curve-fit routine, including orbit propagation based on actual daily solar flux record, was applied to the TLE history until an A/m value converged to fit the data. At the end of the data processing, good A/M solutions were obtained for the majority of the fragments. Figure 2 shows the size versus A/m distributions of the four fragment clouds. Objects with an A/m close to or above ~1 m^2/kg are probably multi-layer insulation (MLI) pieces. Objects with an A/m between ~0.2 to ~1 m^2/kg are likely to be made of a honeycomb of composite materials. Objects with an A/m below ~0.2 m^2/kg are consistent with heavy metal-like debris.

The distribution of the FY-1C fragments indicates a complete fragmentation of the vehicle and many debris originated from possibly the MLIs, the two large solar panels (1.5 m × 4 m each), and other plastic components. The distribution of the Cosmos 2251 fragments also shows various components in the mix.

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Table 1. A summary of recent major breakups (based on the 25 June 2009 catalog data).

Event	Event Time	Cause	Total Cataloged Fragment	Number of Cataloged Fragments with RCS data	Number of Cataloged Fragments Remaining In Orbit
Fengyun-1C	Jan 2007	Collision (deliberate)	2529	2529	2479
Briz-M	Feb 2007	Explosion	76	76	74
Cosmos 2421	Mar 2008	Unknown	509	508	41
Iridium 33	Feb 2009	Collision (accidental)	336	327	323
Cosmos 2251	Feb 2009	Collision (accidental)	795	789	773

*some tracked objects have not been added to the catalog.

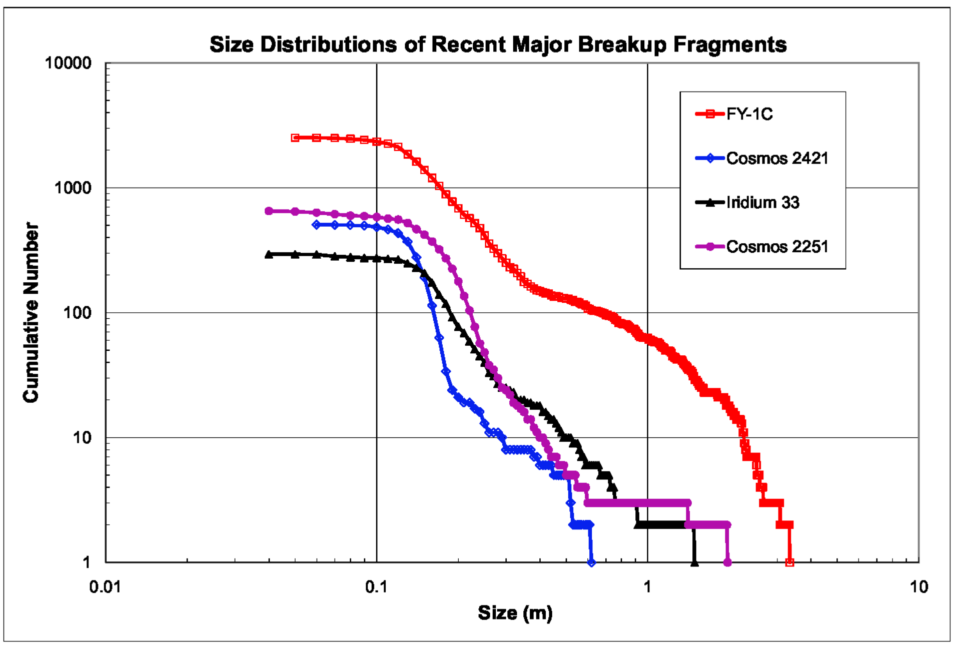

Figure 1. Cumulative size distributions of the four major breakup fragment clouds since 2007.

Reentry Survivability

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The distribution of the Iridium 33 fragments, however, is more unusual. The lack of metal-like fragments could be a reflection of the extensive usage of lightweight composite materials for the construction of the satellite.[5] Many of the fragments may also originate from the two solar arrays (3.9 m^2 each) and/or the three main mission antennas (1.6 m^2 each). Spectroscopic observations on some of the fragments might provide additional insight on their origins.

1. Johnson, N. et al., *History of on-orbit satellite fragmentations*, 14^{th} edition, NASA/TM–2008–214779, 2008.

2. Johnson, N. et al., *The characteristics and consequences of the break-up of the Fengyun-1C spacecraft*, Acta Astronautica 63, 128-135, 2008.

3. Liou, J.-C. and Johnson, N., *Characterization of the cataloged Fengyun-1C fragments and their long-term effect on the LEO environment*, Adv. Space Res. 43, 1407-1415, 2009.

4. Setteceri, T. et al., *Radar measurements of the orbital debris environment: Haystack and HAX radars October 1990 – October 1998*, JSC-28744, 1999.

5. Garrison, T. et al., *System engineering trades for the Iridium constellation*, J. Spacecraft & Rockets 34, 675-680, 1997. ♦

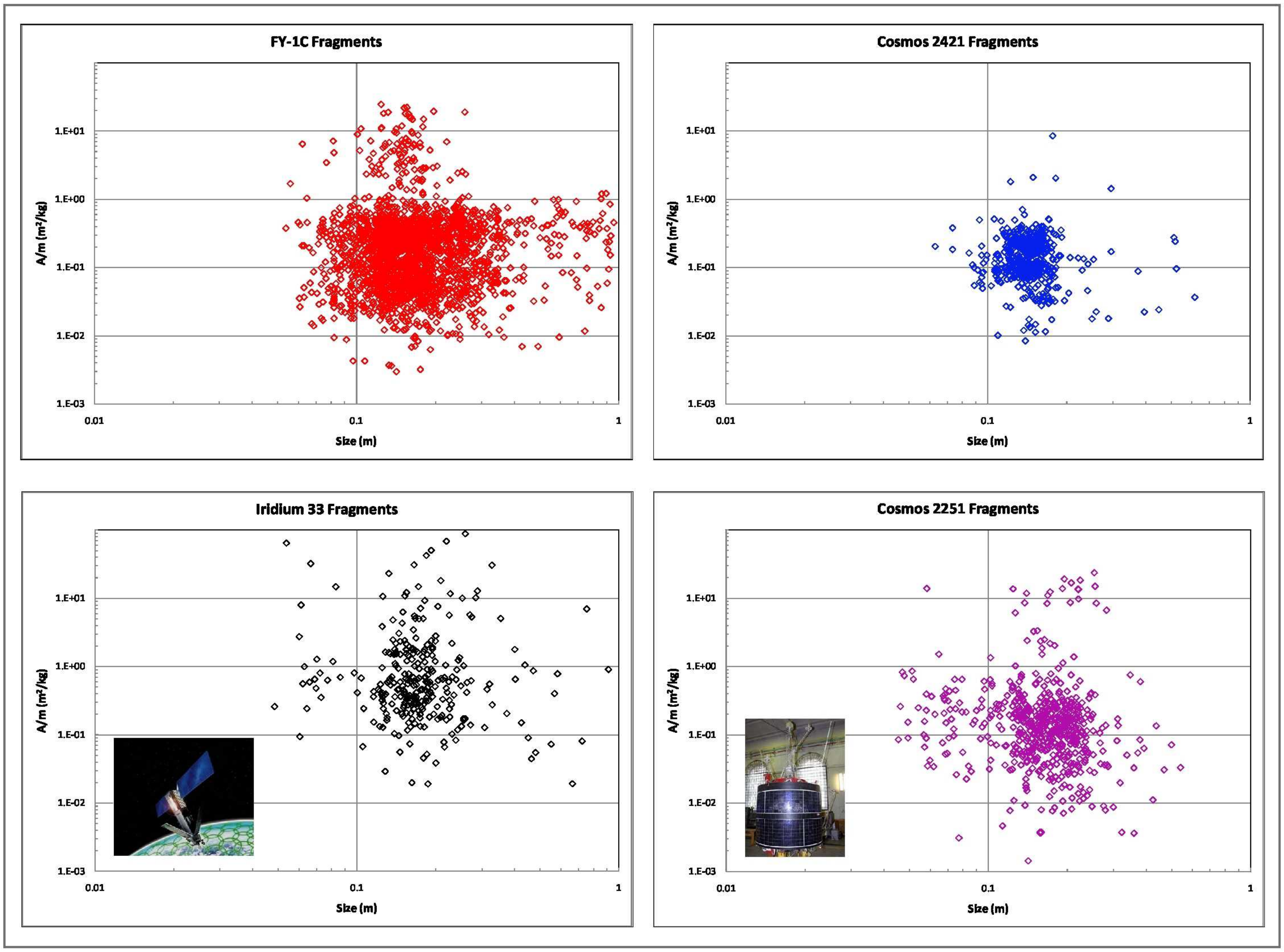


Figure 2. Area-to-mass (A/m) ratio versus size distributions of the four major fragment clouds.

Visit the NASA Orbital Debris Program Office Website
www.orbitaldebris.jsc.nasa.gov

UPCOMING MEETINGS

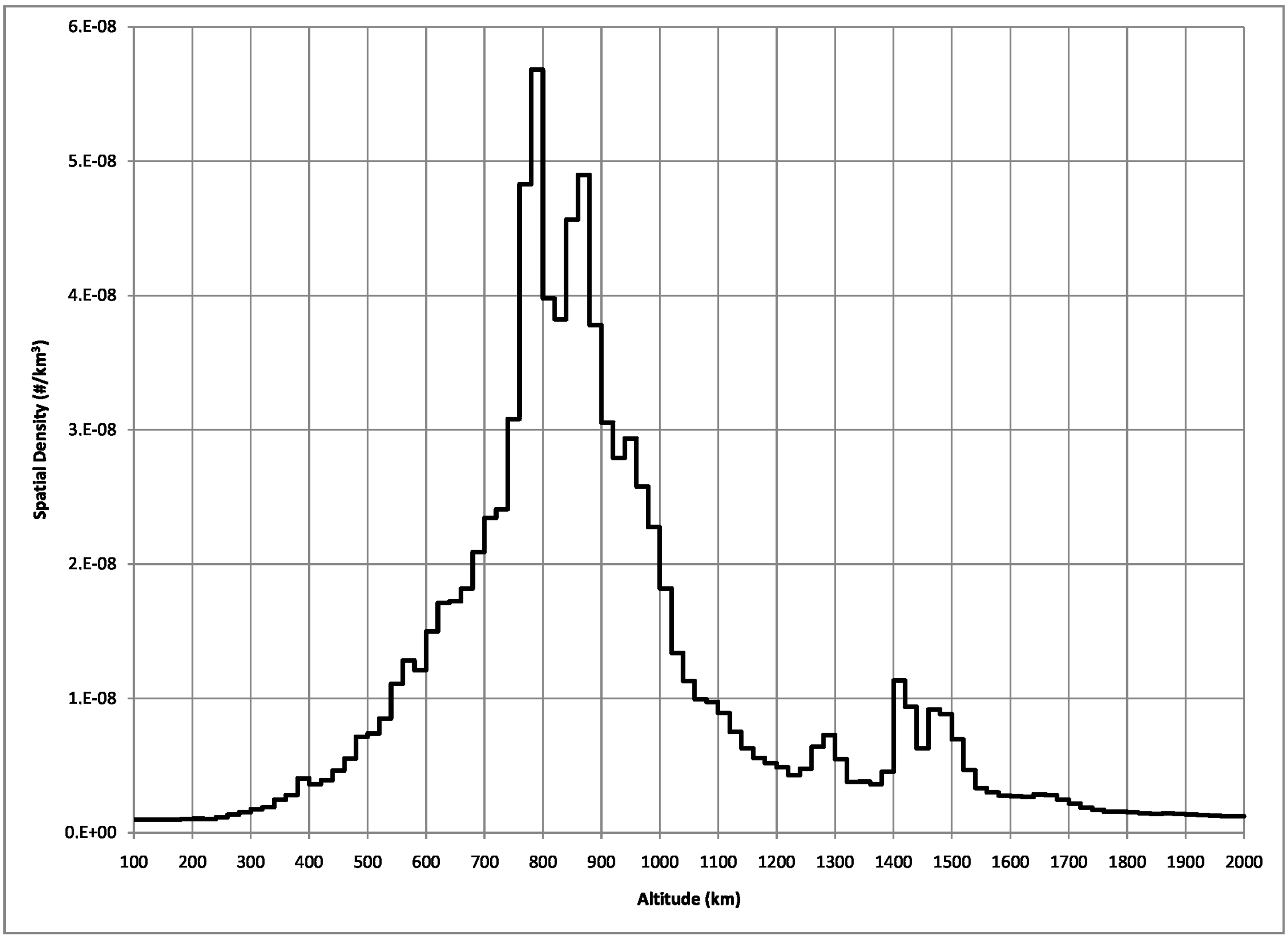
12-16 October 2009: The 60th International Astronautical Congress (IAC), Daejeon, Republic of Korea

The theme of the 2009 IAC is "Space for Sustainable Peace and Progress." A total of five sessions are planned for the Space Debris Symposium. The subjects of the sessions include measurements and space surveillance, modeling and risk analysis, hypervelocity impacts and protection, and mitigation and standards. Additional information on the 2009 IAC is available at <http://www.iac2009.kr/>.

1-4 September 2009: Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference, Maui, Hawaii, USA

The 10th annual AMOS Conference will continue to focus on space surveillance. Three sessions are planned for orbital debris, Iridium/Cosmos collision, and space situational awareness. Additional information on the conference is available at <http://www.amostech.com>.

Current Debris Environment in Low Earth Orbit



Low Earth orbit spatial density (in 20 km bins) of the cataloged objects (as of 5 June 2009).

SATELLITE BOX SCORE

(as of 01 July 2009, as cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	77	2855	2932
CIS	1381	3637	5018
ESA	39	36	75
FRANCE	49	410	459
INDIA	36	115	151
JAPAN	114	71	185
USA	1101	3449	4550
OTHER	429	98	527
TOTAL	3226	10671	13897

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DAS 2.0 NOTICE

Attention DAS 2.0 Users: An updated solar flux table is available for use with DAS 2.0. Please go to the Orbital Debris Website (http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html) to download the updated table and subscribe for email alerts of future updates.

INTERNATIONAL SPACE MISSIONS

01 April – 30 June 2009

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2009-001A	USA 202	USA	NO ELEMS. AVAILABLE			1	0
2009-002A	GOSAT	JAPAN	668	670	98.0	1	2
2009-002B	PRISM	JAPAN	612	642	98.0		
2009-002C	SDS-1	JAPAN	662	668	98.0		
2009-002D	OBJECT D	JAPAN	655	666	98.0		
2009-002E	OBJECT E	JAPAN	658	668	98.0		
2009-002F	OBJECT F	JAPAN	667	671	98.0		
2009-002G	STARS	JAPAN	648	666	98.0		
2009-002H	KKS-1	JAPAN	652	666	98.0		
2009-003A	KORONAS-FOTON	RUSSIA	539	562	82.5	1	0
2009-004A	OMID	IRAN	245	378	55.5	1	0
2009-005A	NOAA 19	USA	845	867	98.7	1	0
2009-006A	PROGRESS-M 66	RUSSIA	348	360	51.6	1	0
2009-007A	EXPRESS AM-44	RUSSIA	35774	35800	0.1	1	1
2009-007B	EXPRESS MD1	RUSSIA	35783	35790	0.1		
2009-008A	NSS 9	NETHER-LANDS	35778	35794	0.0	1	1
2009-008B	HOT BIRD 10	EUTELSAT	35783	35791	0.1		
2009-008C	SPIRALE A	FRANCE	621	35703	1.9		
2009-008D	SPIRALE B	FRANCE	630	35694	1.9		
2009-009A	TELSTAR 11N	CANADA	35782	35791	0.0	1	0
2009-010A	RADUGA 1-8	RUSSIA	35614	35946	1.4	2	3
2009-011A	KEPLER	USA	HELIOCENTRIC			1	1
2009-012A	STS 119	USA	335	353	51.6	0	0
2009-013A	GOCE	ESA	271	288	96.7	1	0
2009-014A	NAVSTAR 63 (USA 203)	USA	20025	20089	55.0	2	0
2009-015A	SOYUZ-TMA 14	RUSSIA	347	360	51.6	1	0

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